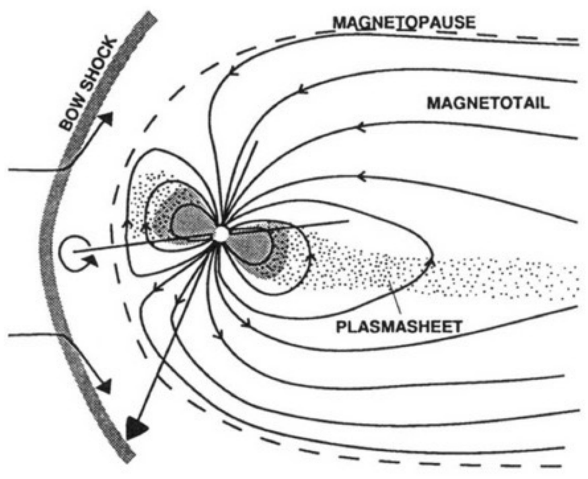

Re-exploring the radio spectrum of Uranus in orbit : science case and digital high frequency receiver

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ABSTRACT

Among the known planetary magnetospheres, those of Uranus and Neptune display very similar radio environments so that they have early been referred to as 'radio twins'. Their pioneer exploration by the Voyager 2 Planetary Radioastronomy experiment revealed a variety of electromagnetic radio waves ranging from ~0 to a few tens of MHz similar to - although more complex than - those of Saturn or the Earth. Nonetheless, the asymmetric magnetosphere of Uranus is unavoidably the most atypical with a large obliquity, magnetic tilt and fast rotation period, so that the magnetosphere undergoes perpetual geometric reconfiguration. In this contribution, we review the various and complex Uranian radio emissions, including the auroral Uranian Kilometric Radiation (UKR) between a few 10kHz and 1 MHz, Uranian Electrostatic Discharges (UED) observed up to 40 MHz, and low frequency waves (continuum, whistler mode emissions) observed at a few kHz. We then present a modern concept of digital High Frequency Receiver (HFR) within the framework of a general Radio and Plasma Wave (RPW) experiment to be proposed to a future NASA/ESA orbital mission toward Uranus. This HFR concept, updated from the heritage of Cassini/RPWS/HFR, Bepi-Clompobo/PWI/Sorbet or Solar Orbiter/RPW is aimed at providing a light, robust, low-consumption versatile instrument capable of goniopolarimetric and waveform measurements from a few kHz to ~40MHz, devoted to the study of radio emissions, plasma waves and dust impacts.

URANUS AS A RADIO SOURCE

TABLE 1

Components	Spectrum	Polar.	Mode	Modulation	Source	Generation
UED	1-40 MHz	-	free space	episodes ~min-h	Atmosphere	Lightning discharges
UKR - b-smooth	150-900 kHz	LH	R-X	rotation, Ariel ?	S mag. pole	Cyclotron Maser Instability
UKR - n-smooth	20-350 kHz	RH/LH	R-X	rotation	Mag. equator	
UKR - dayside	100-300 kHz	LH	L-O	rotation	N mag. pole	
UKR - b-bursts	200-800 kHz	LH	R-X	rotation, 30Hz	S mag. pole	
UKR - n-bursts	16-117 kHz	RH	R-X	SW	N cusp ?	
Continuum	<6-60kHz	RH	L-O	rotation	Mag. equator	es/em
5 kHz noise	3-10 kHz	?	whistler	-	Miranda	es/em

Table 1 : Radio emissions from Uranus **[1]**.

FIGURE 1

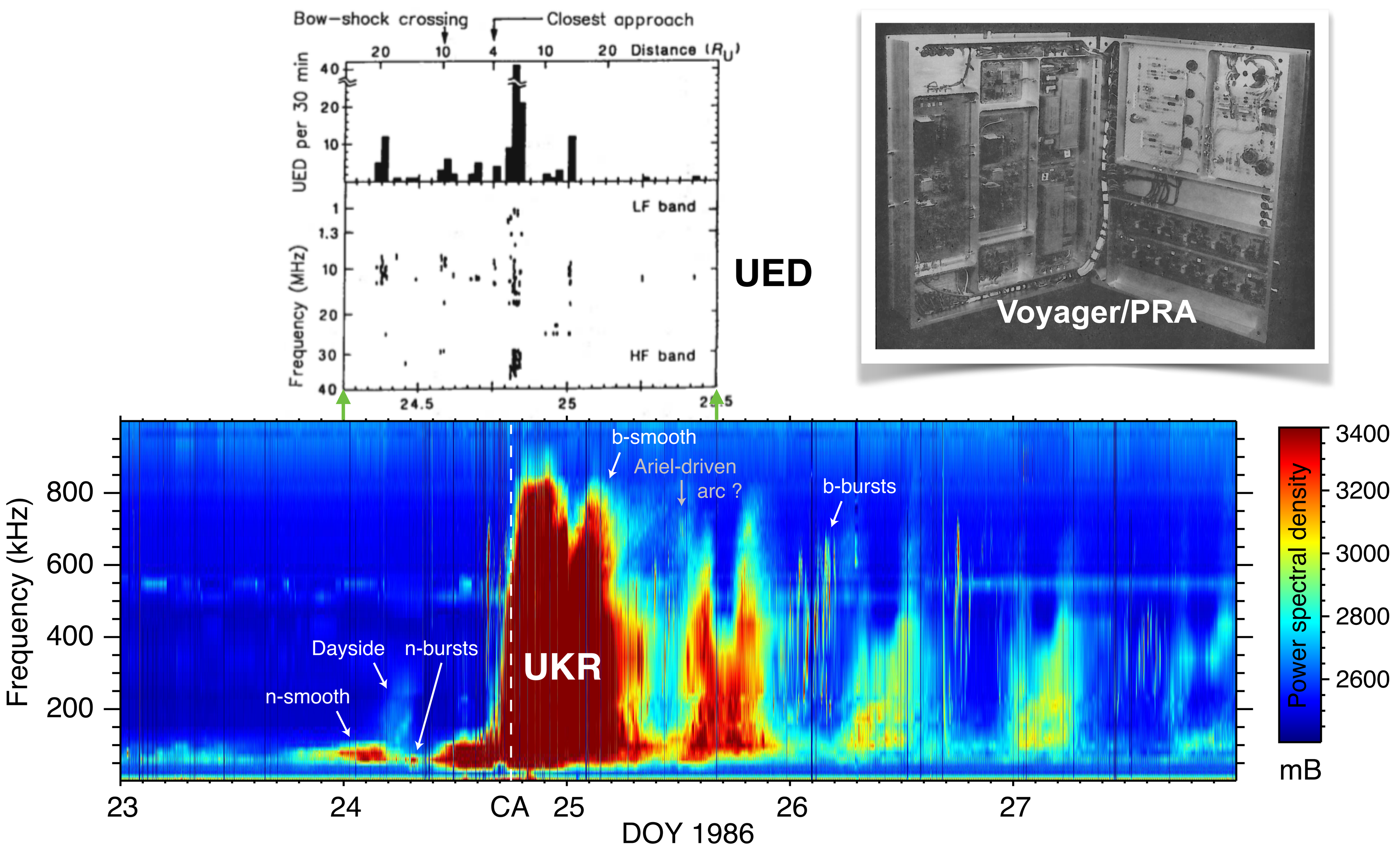


Figure 1 : Voyager 2/PRA observations of (top) UED >1MHz and (bottom) UKR <1MHz **[1]**.

FIGURE 2

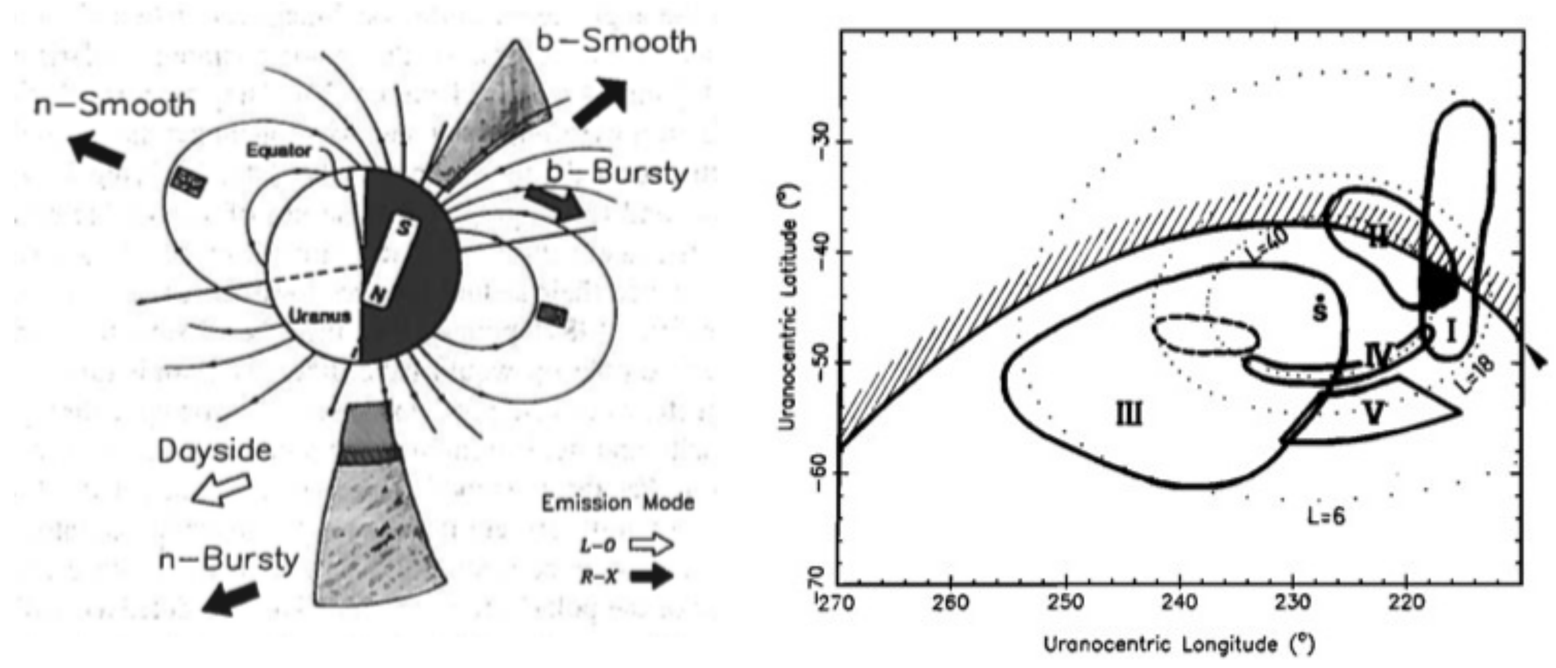


Figure 2 : Locus of UKR sources and polar projection of nightside emissions **[1]**.

FIGURE 3

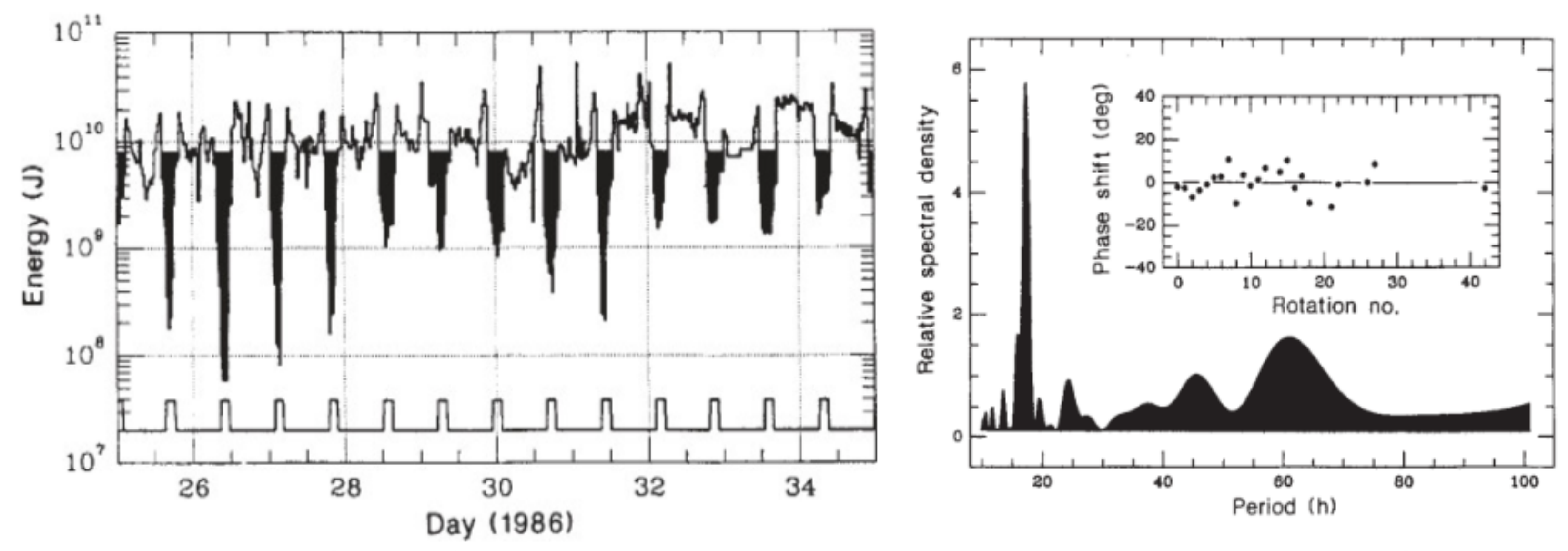


Figure 3 : UKR rotational modulation and FFT-derived radio period **[1]**.

RE-OBSERVING THE RADIO SPECTRUM OF URANUS

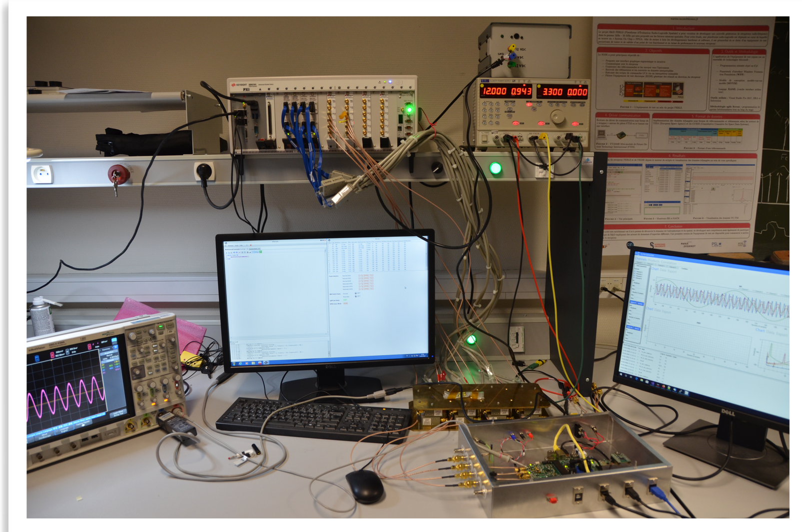
Unless building a large radiotelescope on the farside of the moon, re-observing the radio spectrum from Uranus requires a dedicated exploration probe equipped with an adequate Radio and Plasma Wave (RPW) experiment including 10-m class electric antenna and sensitive radio receivers. Such an instrument and the large science case it would address have been detailed in several missions concepts proposed to explore the Uranian system **[e.g. 3-11]**.

High Frequency radio measurements from ~5 kHz up ~40 MHz would monitor all the radio components displayed in table 1 and in Figs. 1-3 and help to address the following questions :

- What is **specific to Ice giant auroral radio emissions** ? How are they **produced** ? What is the **source of free energy** driving their unique smooth components ? What makes the **magnetic equatorial region an auroral radio source** ?
- What is the internal **rotation rate** ? What is the overall magnetospheric configuration ? What are the **relative roles of rotation, solar wind and moons** in driving magnetospheric dynamics and particle acceleration processes ?
- What makes the **specificity of ice giant lightnings** ? How does the ionosphere vary with time ?
- How are **dusty rings** structured and how do they evolve ?

Cruise objectives : Such radio measurements would also remotely track Jupiter's auroral radio magnetospheric activity from long distances (even without a flyby) and solar radio emissions/local plasma waves in the outer heliosphere.

FIGURE 4



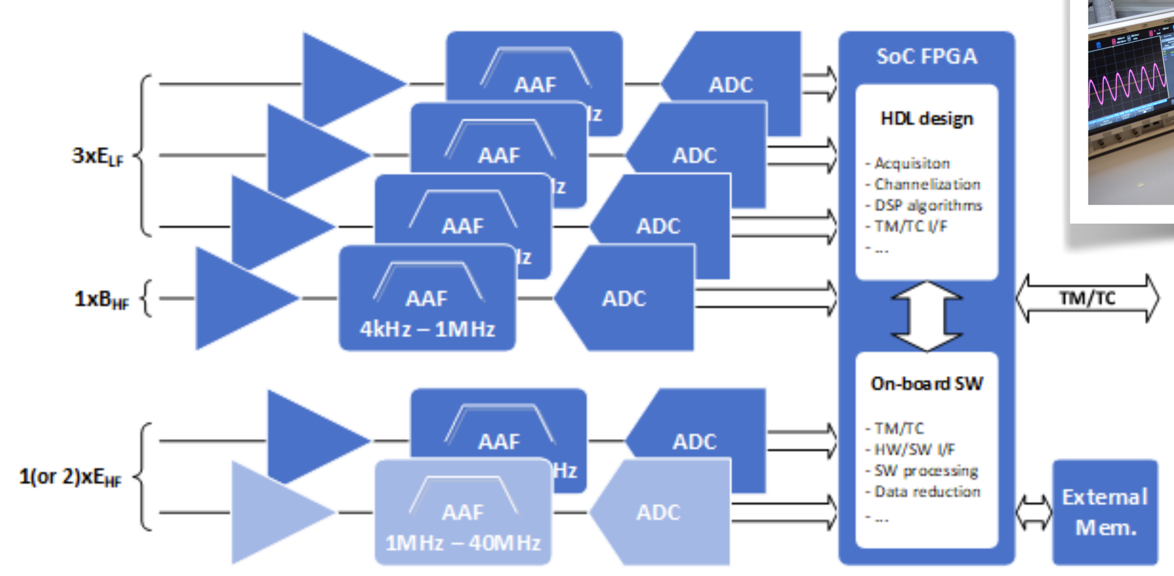


Figure 4 : Schematics of the HFR concept based on the PERLS program developed at LESIA.

A BROADBAND DIGITAL HIGH FREQUENCY RECEIVER

Based on a long heritage for designing, conceiving and exploiting spatial radio measurements, we proposed a light, robust and low-consumption fully digital receiver concept, illustrated in Fig. 4 with the following characteristics :

- **Spectral range** : 5 kHz to 40 MHz, covered by two bands
- **Channels/sensors** :
  - Low band (<1 MHz, UKR, LF waves) : 3E baseline +1B in option
  - High band (>1MHZ, UED, Jupiter, Sun) : 1E until 40 MHz or 2E until 25 MHz
  - Direct digitization (16 bits-ADC), 120 dB dynamics
- **Performances :** t-f mode with full auto-/cross-correlations (3-antenna goniopolarimetry <1MHz), waveform capture (5Msps / channel) < 1MHz
- **Size :** 160x240x25 mm (1 PCB card)
- **Weight :** 500g excluding harnesses and electronic box
- **Power** : 3.5 W in average + 0.6 W (for 3 pre-amplifiers)
- **Telemetry :** typical rate of a few kbps (minimzed by exploiting operational modes, data onboard storage and compression)
- **Heritage** : Cassini/RPWS/HFR, Bepi-Colombo/PWI/Sorbet, Solar Orbiter/RPW and JUICE/RPWI/JENRAGE, R&D CNES project PERLS
- **TRL** : 6

REFERENCES

[1] Desch, M. et al., *Uranus as a radio source*, in Uranus, Univ. of Arizona press, 1991.
[2] Desch et al., The rotation period of Uranus, Nature, 1986
[3] Hess, S. et al., *Exploration of the Uranus magnetosphere*, white paper submitted to the solar and heliosphere decadal survey 2013-2022, 2011.
[4] Rymer, A. et al., *The case for exploring Uranus' magnetosphere*, white paper submitted to the solar and heliosphere decadal survey 2013-2022, 2011.
[5] Arridge, C. et al., *Uranus Pathfinder: exploring the origins and evolution of Ice Giant planets*, Exp. Astron., 2011.
[6] Arridge, C. et al., *The science case for an orbital mission to Uranus: Exploring the origins and evolution of ice giant planets*, Planet. Sp. Sci., 2014.
[7] Fletcher, L. et al., *Ice giants systems : the scientific potential of mission to the Uranus and Neptune systems*, ESA Voyage 2050 call, 2019.
[8] Blanc, M. et al., *Science Goals and Mission Objectives for the Future Exploration of Ice Giants Systems: A Horizon 2061 Perspective*, Space Science Reviews, 2021.
[9] Arridge C. et al., *Fundamental Space Physics in Uranus' Magnetosphere*, white paper submitted to the solar and heliosphere decadal survey 2024-2033, 2022.
[10] Cao, X. et al., *Science Return of Probing Magnetospheric Systems of Ice Giants*, white paper submitted to the solar and heliosphere decadal survey 2024-2033, 2022.
[11] Cohen I. et al., *The case for studying other planetary magnetospheres and atmospheres in Heliophysics*, white paper submitted to the solar and heliosphere decadal survey 2024-2033, 2022.